Integration of energy efficient appliances with the buildings

Energy efficiency:

• It means getting the most from every energy unit by using state-of-the-art technologies to provide the daily needs like comfortable homes, profitable business and convenient transportation.

• It is a cheap, clean way to reduce energy use and pollution

• Replace just four 100-watt incandescent bulbs that burn four or more hour a day at home with four 23-watt fluorescent bulbs, you'd get as much light and save at least 1356kWh of electricity.

• Building Integrated Solar Thermal (BIST) Technologies

Building-integrated photovoltaics

Building-integrated photovoltaics (**BIPV**) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or ancillary source of electrical power, although existing buildings may be retrofitted with similar technology. The advantage of integrated photovoltaics over more common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labour that would normally be used to construct the part of the building that the BIPV modules replace. These advantages make BIPV one of the fastest growing segments of the photovoltaic industry. The term **building-applied photovoltaics** (**BAPV**) is sometimes used to refer to photovoltaics that are a retrofit – integrated into the building after construction is complete. Most building-integrated installations are actually BAPV. Some manufacturers and builders differentiate new construction BIPV from BAPV.

History

PV (**photovoltaics**) applications for buildings began appearing in the 1970s. Aluminium-framed photovoltaic modules were connected to, or mounted on, buildings that were usually in remote areas without access to an electric power grid. In the 1980s photovoltaic module add-ons to roofs began being demonstrated. These PV systems were usually installed on utility-grid-connected buildings in areas with centralized power stations. In the 1990s BIPV construction products specially designed to be integrated into a building envelope became commercially available. Despite technical promise, social barriers to widespread use have also been identified, such as the conservative culture of the building industry and integration with high-density urban design. These authors suggest enabling long-term use likely depends on effective public policy decisions as much as the technological development.

Forms

There are four main types of BIPV products:

- Crystalline silicon solar panels for ground-based and rooftop power plant
- Amorphous crystalline silicon thin film solar PV modules which could be hollow, light, red blue yellow, as glass curtain wall and transparent skylight
- CIGS-based (Copper Indium Gallium Selenide) thin film cells on flexible modules laminated to the building envelope element or the CIGS cells are mounted directly onto the building envelope substrate
- Double glass solar panels with square cells inside

Building-Integrated Photovoltaic modules are available in several forms:

- Flat roofs
  - The most widely installed to date is an amorphous thin film solar cell integrated to a flexible polymer module which has been attached to the roofing membrane using an adhesive sheet between the solar module back sheet and the roofing membrane.
- Pitched roofs
  - Solar roof tiles are (ceramic) roof tiles with integrated solar modules. The ceramic solar roof tile is developed and patented by a Dutch company in 2013.
  - Modules shaped like multiple roof tiles.
  - Solar shingles are modules designed to look and act like regular shingles, while incorporating a flexible thin film cell.
  - It extends normal roof life by protecting insulation and membranes from ultraviolet rays and water degradation. It does this by eliminating condensation because the dew point is kept above the roofing membrane.

Metal pitched roofs (both structural and architectural) are now being integrated with PV functionality either by bonding a free-standing flexible module or by heat and vacuum sealing of the CIGS cells directly onto the substrate

- Facade
    - Facades can be installed on existing buildings, giving old buildings a whole new look. These modules are mounted on the facade of the building, over the existing structure, which can increase the appeal of the building and its resale value.
- Glazing
    - Photovoltaic windows are (semi)transparent modules that can be used to replace a number of architectural elements commonly made with glass or similar materials, such as windows and skylights. In addition to producing electric energy, these can create further energy savings due to superior thermal insulation properties and solar radiation control.

Transparent and translucent photovoltaics

Transparent solar panels use a tin oxide coating on the inner surface of the glass panes to conduct current out of the cell. The cell contains titanium oxide that is coated with a photoelectric dye. Most conventional solar cells use visible and infrared light to generate electricity. In contrast, the innovative new solar cell also uses ultraviolet radiation. Used to replace conventional window glass, or placed over the glass, the installation surface area could be large, leading to potential uses that take advantage of the combined functions of power generation, lighting and temperature control. Another name for transparent photovoltaics is "translucent photovoltaics" (they transmit half the light that falls on them). Similar to inorganic photovoltaics, organic photovoltaics are also capable of being translucent.

Types of transparent and translucent photovoltaics

Non-wavelength-selective

Some non-wavelength-selective photovoltaics achieve semi-transparency by spatial segmentation of opaque solar cells. This method uses any type of opaque photovoltaic cell and spaces several small cells out on a transparent substrate. Spacing them out in this way reduces power conversion efficiencies dramatically while increasing transmission. Another branch of non-wavelength-selective photovoltaics utilize visibly absorbing thin-film semi-conductors with small thicknesses or large enough band gaps that allow light to pass through. This results in semi-transparent photovoltaics with a similar direct trade off between efficiency and transmission as spatially segmented opaque solar cells.

Wavelength-selective

Wavelength-selective photovoltaics achieve transparency by utilizing materials that only absorb UV and/or NIR light and were first demonstrated in 2011. Despite their higher transmissions, lower power conversion efficiencies have resulted due to a variety of challenges. These include small exciton diffusion lengths, scaling of transparent electrodes without jeopardizing efficiency, and general lifetime due to the volatility of organic materials used in TPVs in general.

Innovations in transparent and translucent photovoltaics

Early attempts at developing non-wavelength-selective semi-transparent organic photovoltaics using very thin active layers that absorbed in the visible spectrum were only able to achieve efficiencies below 1%. However, in 2011, transparent organic photovoltaics that utilized an organic chloroaluminum phthalocyanine (ClAlPc) donor and a fullerene acceptor exhibited absorption in the ultraviolet and near-infrared (NIR) spectrum with efficiencies around 1.3% and visible light transmission of over 65%.

Perovskite solar cells, popular due to their promise as next-generation photovoltaics with efficiencies over 25%, have also shown promise as translucent photovoltaics. In 2015, a semi-transparent perovskite solar cell using a methylammonium lead triiodide perovskite and a silver nanowire mesh top electrode demonstrated 79% transmission at an 800 nm wavelength and efficiencies at around 12.7%.

Government subsidies

In some countries, additional incentives, or subsidies, are offered for building-integrated photovoltaics in addition to the existing feed-in tariffs for stand-alone solar systems. Since July 2006 France offered the highest incentive for BIPV, equal to an extra premium of EUR

0.25/kWh paid in addition to the 30 Euro cents for PV systems. These incentives are offered in the form of a rate paid for electricity fed to the grid.

Design of a Building Integrated Photovoltaics (BIPV) System

BIPV systems should be approached to where energy conscious design techniques have been employed, and equipment and systems have been carefully selected and specified. They should be viewed in terms of life-cycle cost, and not just initial, first-cost because the overall cost may be reduced by the avoided costs of the building materials and labour they replace. Design considerations for BIPV systems must include the building's use and electrical loads, its location and orientation, the appropriate building and safety codes, and the relevant utility issues and costs. Steps in designing a BIPV system include:

1) Carefully consider the application of energy-conscious design practices and/or energy efficiency measures to reduce the energy requirements of the building. This will enhance comfort and save money while also enabling a given BIPV system to provide a greater percentage contribution to the load.

2) Choose Between a Utility-Interactive PV System and a Stand-alone PV System:

The vast majority of BIPV systems will be tied to a utility grid, using the grid as storage and backup. The systems should be sized to meet the goals of the owner—typically defined by budget or space constraints; and, the inverter must be chosen with an understanding of the requirements of the utility.

For those 'stand-alone' systems powered by PV alone, the system, including storage, must be sized to meet the peak demand/lowest power production projections of the building. To avoid over sizing the PV/battery system for unusual or occasional peak loads, a backup generator is often used. This kind of system is sometimes referred to as a "PV-genset hybrid."

3) Shift the Peak: If the peak building loads do not match the peak power output of the PV array, it may be economically appropriate to incorporate batteries into certain grid-tied systems to offset the most expensive power demand periods. This system could also act as an uninterruptible power system (UPS).

4) Provide Adequate Ventilation: PV conversion efficiencies are reduced by elevated operating temperatures. This is truer with crystalline silicon PV cells than amorphous silicon thin-films. To improve conversion efficiency, allow appropriate ventilation behind the modules to dissipate heat.

5) Evaluate Using Hybrid PV-Solar Thermal Systems: As an option to optimize system

efficiency, a designer may choose to capture and utilize the solar thermal resource developed through the heating of the modules. This can be attractive in cold climates for the pre-heating of incoming ventilation make-up air.

6) Consider Integrating Daylighting and Photovoltaic Collection: Using semi-transparent thin film modules, or crystalline modules with custom-spaced cells between two layers of glass, designers may use PV to create unique daylighting features in façade, roofing, or skylight PV systems. The BIPV elements can also help to reduce unwanted cooling load and glare associated with large expanses of architectural glazing.

7) Incorporate PV Modules into Shading Devices: PV arrays conceived as "eyebrows" or awnings over view glass areas of a building can provide appropriate passive solar shading. When sunshades are considered as part of an integrated design approach, chiller capacity can often be smaller and perimeter cooling distribution reduced or even eliminated.

8) Design for the Local Climate and Environment: Designers should understand the impacts of the climate and environment on the array output. Cold, clear days will increase power production, while hot, overcast days will reduce array output;

- Surfaces reflecting light onto the array (e.g., snow) will increase the array output;
- Arrays must be designed for potential snow- and wind-loading conditions;
- Properly angled arrays will shed snow loads relatively quickly; and,
- Arrays in dry, dusty environments or environments with heavy industrial or traffic (auto, airline) pollution will require washing to limit efficiency losses.

9) Address Site Planning and Orientation Issues: Early in the design phase, ensure that your solar array will receive maximum exposure to the sun and will not be shaded by site obstructions such as nearby buildings or trees. It is particularly important that the system be completely unshaded during the peak solar collection period consisting of three hours on either side of solar noon. The impact of shading on a PV array has a much greater influence on the electrical harvest than the footprint of the shadow.

10) Consider Array Orientation: Different array orientation can have a significant impact on the annual energy output of a system, with tilted arrays generating 50%-70% more electricity than a vertical façade. Reduce Building Envelope and Other On-site Loads: Minimize the loads experienced by the BIPV system. Employ daylighting, energy-efficient motors, and other peak reduction strategies whenever possible.

11) Professionals: The use of BIPV is relatively new. Ensure that the design, installation, and maintenance professionals involved with the project are properly trained, licensed, certified,

and experienced in PV systems work. In addition, BIPV systems can be designed to blend with traditional building materials and designs, or they may be used to create a high-technology, future-oriented appearance. Semi-transparent arrays of spaced crystalline cells can provide diffuse, interior natural lighting. High profile systems can also signal a desire on the part of the owner to provide an environmentally conscious work environment. There is a growing consensus that distributed photovoltaic systems that provide electricity at the point of use will be the first to reach widespread commercialization. Chief among these distributed applications are PV power systems for individual buildings.

APPLICATION

Photovoltaics may be integrated into many different assemblies within a building envelope:

❖ Solar cells can be incorporated into the façade of a building, complementing or replacing traditional view or spandrel glass. Often, these installations are vertical, reducing access to available solar resources, but the large surface area of buildings can help compensate for the reduced power.

❖ Photovoltaics may be incorporated into awnings and saw-tooth designs on a building façade. These increase access to direct sunlight while providing additional architectural benefits such as passive shading.

❖ The use of PV in roofing systems can provide a direct replacement for batten and seam metal roofing and traditional 3-tab asphalt shingles.

❖ Using PV for skylight systems can be both an economical use of PV and an exciting design feature.

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